The Non-Damped Nature of Twelve Low-Redshift Damped Lyα Candidate Systems[1]

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ABSTRACT

Hubble Space Telescope (*HST*) UV spectroscopy of 12 candidate low-redshift damped Lyα (DLA) systems in 11 QSOs ($z = 0.103$ in Q0054+144, $z = 0.969$ and $z = 0.987$ in Q0302−223, $z = 0.478$ in Q0454−220, $z = 1.476$ in Q1047+550, $z = 1.070$ in Q1206+459, $z = 1.228$ in Q1247+267, $z = 0.399$ in Q1318+290B, $z = 0.519$ in Q1329+412, $z = 0.276$ in Q1451−375, $z = 0.204$ in Q2112+059, $z = 0.263$ in Q2251+113) are presented; the observations demonstrate that they are not DLAs with $N_{HI} \geq 2 \times 10^{20}$ atoms cm^{-2}. In all cases except two the systems either do not exist or are well below the DLA threshold column density; the exceptions are a $z = 0.474$ system in Q0454−220 which has $N_{HI} = 3 \times 10^{19}$ atoms cm^{-2} and a $z = 1.223$ system in Q1247+267 which has $N_{HI} = 8 \times 10^{19}$ atoms cm^{-2}. Despite the availability of data in the *HST* archives demonstrating that these are not suitable targets, many have unfortunately been approved for observation with *Chandra*, *Gemini*, and/or *HST* with the intent of doing followup work on low-redshift DLAs. Furthermore, these results indicate that the low-redshift DLA statistics derived from *IUE* spectra and presented by Lanzetta, Wolfe, & Turnshek (1995) and Wolfe et al. (1995) are invalid.

Subject headings: quasars: absorption lines — quasars: individual (Q0054+144, Q0215+015, Q0302−223, Q0454−220, Q0935+417, Q1047+550, Q1206+459, Q1247+267, Q1318+290B, Q1329+412, Q1451−375, Q2112+059, Q2223−052, Q2251+113) — galaxy formation

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1. INTRODUCTION

Damped Lyα (DLA) QSO absorption line systems trace the neutral gas in the non-local Universe. Consequently, studies of DLAs are used to investigate many fundamental problems in galaxy formation research, from measurements of the evolution of the cosmological mass density and extent of the neutral gas component, to studies of the types of galactic reservoirs that harbor the neutral gas, to measurements of the neutral-gas-phase cosmic metallicity. However, despite recent successes in identifying DLAs at low redshifts (Rao & Turnshek 2000, hereafter RT2000), they are still relatively rare, with fewer than 30 now known at redshifts $z < 1.65$ corresponding to the wavelength where the Lyα line falls in the UV shortward of the earth's atmospheric transmission cutoff.

Unfortunately, part of the extragalactic astronomy community has recently been confused about the reality of some low-redshift DLA systems. Initial confusion probably stemmed from a lack of distinction between candidate DLA systems, identified by various means, and ones that have been confirmed through UV spectroscopy with adequate resolution and signal-to-noise ratio. In particular, the International Ultraviolet Explorer (*IUE*) study of Lanzetta, Wolfe, & Turnshek (1995, hereafter LWT95) presented a list of low-redshift *candidate* DLA systems, most of which were shown not to be DLAs in followup *HST* UV spectroscopy. Evidently the status of these systems needs to be clarified because investigators are still being awarded time to make followup imaging and metallicity studies of them on *Chandra*, *Gemini*, and *HST*. Moreover, numerous researchers have cited and often used statistical results on low-redshift DLAs that are based on these non-existent DLA systems. Thus, our motivation for writing this short contribution is twofold. First, we wish to inform observers and referees about which candidate low-redshift DLA systems are not confirmed, so as to minimize the possibility that valuable telescope time will be wasted in the future. Second, we wish to correct the record on statistical results which make use of these non-DLA systems. Attempts have been made to clarify the situation in at least two previous refereed papers (Januzzi et al. 1998; RT2000), however those papers did not present the *HST* spectra which prove that the systems are not DLAs, although such evidence was easily accessible in the *HST* archives. In this paper we are more explicit.

The remainder of this paper is therefore broken into two parts. In the first part (§2) we present results on LWT95 candidate DLA systems which have been shown not to be damped based on followup *HST* UV spectroscopy, and we cite some examples of wasted telescope time allocated to observe them. In the second part (§3) we discuss statistical results on low-redshift DLA systems which have been derived using these non-systems, and we identify some prominent results in the literature which make use of or quote these erroneous results.

2. The Non-Damped Low-Redshift DLA Candidate Systems

For technical reasons having to do with the ability to detect DLA systems in the initial survey for them, the study of Wolfe et al. (1986) defined them as those systems with neutral hydrogen column densities $N_{HI} \geq 2 \times 10^{20}$ atoms cm^{-2}; this threshold corresponds to a Lyα absorption line on the "damping" part of the curve-of-growth with a rest equivalent width (REW) of 10 Å. At the time this definition was motivated by instrumental limitations, since systems with lower N_{HI} could not be reliably detected. Thereafter, all surveys for large column density neutral hydrogen systems, and the "DLA" jargon describing them, have adopted this same threshold. In part this is undoubtedly because it was realized that surveys at this threshold capture the bulk of the neutral gas in the Universe out to at least redshift $z < 3.5$. Since the incidence of Lyα absorption systems rises with decreasing N_{HI} for at least $N_{HI} > 10^{13}$ atoms cm^{-2}, it is important to take this threshold into account in any statistical survey. At the same time, the relative rarity of the highest column density systems introduces a statistical uncertainty that is not easy to assess, and there is some worry that the highest N_{HI} systems which are metal-rich and have high dust content could be missed in magnitude-limited surveys due to dimming of the background QSO. But the highest N_{HI} systems are the ones that dominate certain observational determinations of cosmological interest for constraining the galaxy formation process, for example, the mean cosmological mass density of the neutral gas component or the cosmic neutral-gas-phase metallicity, which is a column-density-weighted measurement. Therefore, for example, in these cosmological determinations of the properties of the neutral gas, the discovery and measurement of a high column density system with $N_{HI} = 2 \times 10^{21}$ atoms cm^{-2} will have as much importance or weight as ten DLA systems at the threshold column density value.

The *IUE* study of LWT95 was the first to present an analysis of a large number of UV spectra with the aim of identifying candidate DLA systems at low redshifts ($z < 1.65$). Approximately 260 individual *IUE* spectra were considered in the study. In the final analysis 16 candidate DLA systems were identified in the spectra of 14 QSOs. To be conservative LWT95 included suspected Lyα absorption lines with REWs as low as 5 Å in the candidate DLA list, allowing for the possibility that better data may reveal some of the weaker ones to be true DLA systems with REW$\geq$ 10 Å. Of the 16 candidate systems, four could immediately be ruled out as DLA absorbers (LWT95), leaving the nature of the remaining 12 to be determined using future *HST* UV spectroscopy. Four of these 12 had REW$\geq$ 10 Å, and eight had 10 >REW$\geq$ 5 Å.

HST UV followup spectroscopy is available in the *HST* archives for three of the four LWT95 candidate DLA systems with REW$\geq$ 10 Å, and one has been confirmed as a DLA system (z_{abs} = 1.372 in Q0935+417, Januzzi et al. 1998). The one with REW$\geq$ 10 Å

that has not been observed with *HST* (the $z_{abs} = 0.484$ candidate DLA in Q2223−052, also called 3C446) was observed by Miller & French (1978) and their spectrum does not show the presence of a Mg II$\lambda\lambda$2796,2803 absorption doublet nor a Fe IIλ2600 absorption line at the positions predicted by the candidate system. Based on this information and the RT2000 empirical MgII-FeII selection criterion for DLAs (i.e., DLAs have strong MgII-FeII absorption), it appears highly unlikely that there is a DLA system at this redshift. Chengalur & Kanekar (2000) have also looked for 21 cm absorption at the candidate redshift and did not find any.

HST UV followup spectroscopy is available in the *HST* archives for seven of the eight weaker (10 >REW≥ 5 Å) LWT95 candidate DLA systems. One has been confirmed as a DLA system ($z_{abs} = 1.010$ in Q0302−223, Pettini & Bowen 1997, Boisse et al. 1998, RT2000). The one candidate system which has not been observed in the UV with *HST* ($z_{abs} = 1.342$ in Q0215+015) actually has a strong MgII-FeII system at $z_{abs} = 1.345$ with Mg II λ2796 REW=1.88 Å and Fe II λ2600 REW=1.45 Å (Blades et al. 1982). According to the RT2000 selection criterion for classical DLAs, this system has an $\approx 50\%$ empirical probability of being a DLA; however, this is the highest signal-to-noise ratio *IUE* spectrum used in the LWT95 study and it suggests $N_{HI} = 8 \times 10^{19}$ atoms cm^{-2}, which is also consistent with the findings of RT2000.

Thus, while two of the original 16 LWT95 candidate DLA systems do not have *HST* UV spectroscopy, the evidence suggest that it is unlikely that they are DLAs. The status of all of the LWT95 candidate low-redshift DLA systems is shown in Table 1, along with comments about the assumed reality of the systems at the time of the LWT95 publication. Figure 1 presents the available *HST* UV spectroscopy for the *non-damped* candidates; the wavelength locations of the *non-damped* candidates are marked with arrows.

Despite these results, most of which have been available in the *HST* archives as early as 1996, along with comments in several papers generally pointing out the non-damped nature of many of the LWT95 candidate systems (e.g., Januzzi et al. 1998, RT2000, Fynbo, Moller, & Thomsen 2001, Bechtold et al. 2001), *Chandra*, *Gemini*, and *HST* time have been awarded to followup several of them. For example, a *Chandra* Guest Observer (GO) program to study DLA metallicities included the Q0054+144 candidate DLA in the target list, and *Chandra* observed it. A *Gemini* program was allocated time to perform adaptive-optics imaging of DLA galaxies, and several of the LWT95 non-damped systems were approved targets and were observed, including the Q2251+113 field; the LWT95 paper itself pointed out that while Q2251+113 formally had a candidate DLA system, an existing *HST* spectrum showed that a DLA line was not present. Most recently, *HST* Cycle 11 time was awarded to a GO program in Phase 1 to make spectroscopic metallicity measurements of three of the

LWT95 candidate DLA systems, namely the ones reported in Q0054+144, Q1329+412, and Q2112+059. The Q2112+059 *HST* observation was later dropped in Phase 2. However, as of March 2002, *HST* STIS observations of the Q0054+144 and Q1329+412 DLA candidates are in the "planning" stages, even though they do not exist.

3. Implications for Low-Redshift DLA Statistics

In addition to the issue of wasted telescope time, there is also the issue of adoption of the LWT95 statistical result on DLAs at low redshift. In the LWT95 study it was assumed that the four systems with REW$\geq$ 10 Å were true DLA systems with $N_{HI} \geq 2 \times 10^{20}$ atoms cm^{-2}, while the eight systems with 10 >REW$\geq$ 5 Å were not. These assumptions were used to plot the $z = 0.8$ data points in figures 3, 4, and 6 of LWT95. However, as shown in §2, these were incorrect assumptions. The only system which LWT95 assumed would be confirmed that actually was confirmed was a $z_{abs} = 1.372$ DLA system in Q0935+417; a $z_{abs} = 1.010$ DLA system in Q0302−223 was also confirmed, compensating for the others to some extent. Nevertheless, these results invalidate the $z = 0.8$ data point plotted in figures 3, 4, and 6 of LWT95. One might be tempted to try to infer the real LWT95 low-redshift DLA statistics from these results, however we believe this would be unwise since the redshift path reliably surveyed by the *IUE* spectra is clearly questionable. We note that shortly after the LWT95 study was complete, the LWT95 DLA low-redshift statistics were adopted in the Wolfe et al. (1995) supplemental high-redshift DLA survey.

Turnshek (1997), in a preview of the RT2000 results, first pointed out that the often-cited low-redshift DLA results in LWT95 and Wolfe et al. (1995) were invalid. However, despite this and other concerns which have appeared (Januzzi et al. 1998), many researchers continue to use it, often to infer results on the evolution of DLA systems from high to low redshift. Two of the more relevant and prominent of the investigations are Pei, Fall, & Hauser (1999) and Storrie-Lombardi & Wolfe (2000), but for other investigations that may have used this result see citations to LWT95 and Wolfe et al. (1995) in the NASA Astrophysical Data System Database. The *HST* Mg II survey results presented in RT2000 are currently the only useful statistical results on low-redshift DLAs that are available; unfortunately the error bars on these results are currently quite large, but they are reliable.

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Table 1. Status of Candidate DLA Systems from LWT95

QSO	LWT95 z_{abs}	LWT95 Measured REW (Å)	LWT95 Candidate DLA?	LWT95 Inferred $\log N_{HI}$	Used in LWT95 Low-z DLA Statistics?	HST Confirmed Status	HST Confirmed z_{abs}	HST Confirmed $\log N_{HI}$	Notes
0054+144	0.1030	8.4	Yes	20.1	No	Not DLA	0.1030	18.3	1
0215+015	1.3420	6.4	Yes	19.9	No	See Note	···	···	2
0302−223	0.9690	5.7	Yes	20.0	No	Not DLA	···	···	3
···	0.9874	5.6	Yes	20.0	No	Not DLA	···	···	3
···	1.0140	6.7	Yes	20.0	No	DLA	1.0100	20.4	3
0454−220	0.4778	5.6	No	···	No	Not DLA	0.4738	19.5	4
0935+417	1.3691	10.3	Yes	20.3	Yes	DLA	1.3720	20.5	5
1047+550	1.4762	7.4	Yes	20.0	No	Not DLA	···	···	6
1206+459	1.0699	7.5	No	···	No	Not DLA	···	···	7
1247+267	1.2276	5.8	Yes	19.8	No	Not DLA	1.2232	19.9	8
1318+290B	0.3987	11.9	No	···	No	Not DLA	···	···	9
1329+412	0.5193	17.2	Yes	20.8	Yes	Not DLA	···	···	10
1451−375	0.2761	7.9	Yes	20.1	No	Not DLA	···	···	11
2112+059	0.2039	11.5	Yes	20.4	Yes	Not DLA	···	···	12
2223−052	0.4842	20.3	Yes	20.9	Yes	See Note	···	···	13
2251+113	0.2633	9.0	No	···	No	Not DLA	···	···	14

Note. — (1) Bechtold et al. (2001); (2) No *HST* spectrum available, Blades et al. (1982) find strong MgII-FeII absorption at $z = 1.345$ but the high signal-to-noise ratio *IUE* spectrum gives $N_{HI} = 8 \times 10^{19}$ atoms cm^{-2}; (3) Pettini & Bowen (1997), Boissé et al. (1998), RT2000; (4) *HST* archive, PID 1026, M. Burbidge PI; (5) Jannuzi et al. (1998); (6) *HST* archive, PID 5948, Lanzetta PI; (7) Jannuzi et al. (1998); (8) Pettini et al. (1999); (9) Vanden Berk et al. (1999); (10) *HST* archive, PID 5948, Lanzetta PI; (11) *HST* archive, PID 5948, Lanzetta PI; (12) Fynbo et al. (2001); (13) No *HST* spectrum available, Miller & French (1978) find no MgII or FeII absorption in their optical spectrum, non-detection at 21 cm (Chengalur & Kanekar 2000); (14) Bahcall et al. (1993).

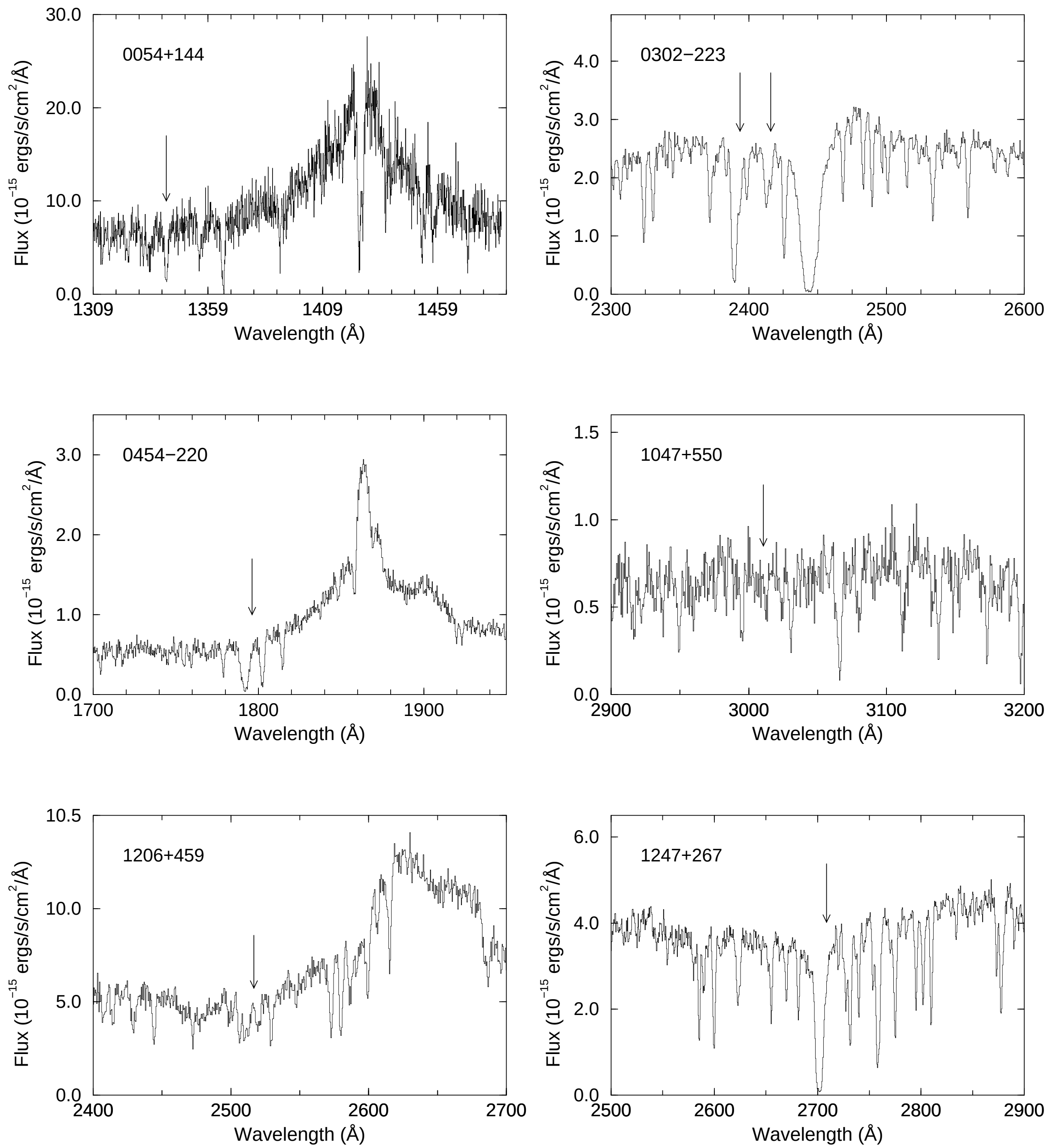

Fig. 1.— HST UV spectra showing the absence of DLA lines at the positions (marked by arrows) predicted by the LWT95 candidate DLA redshifts. The one actual DLA line among these spectra is at 2444 Å in Q0302−223 at $z = 1.0100$. Originally, this QSO had 3 DLA candidates, and the two candidates marked on the Q0302−223 spectrum are the ones ruled out.

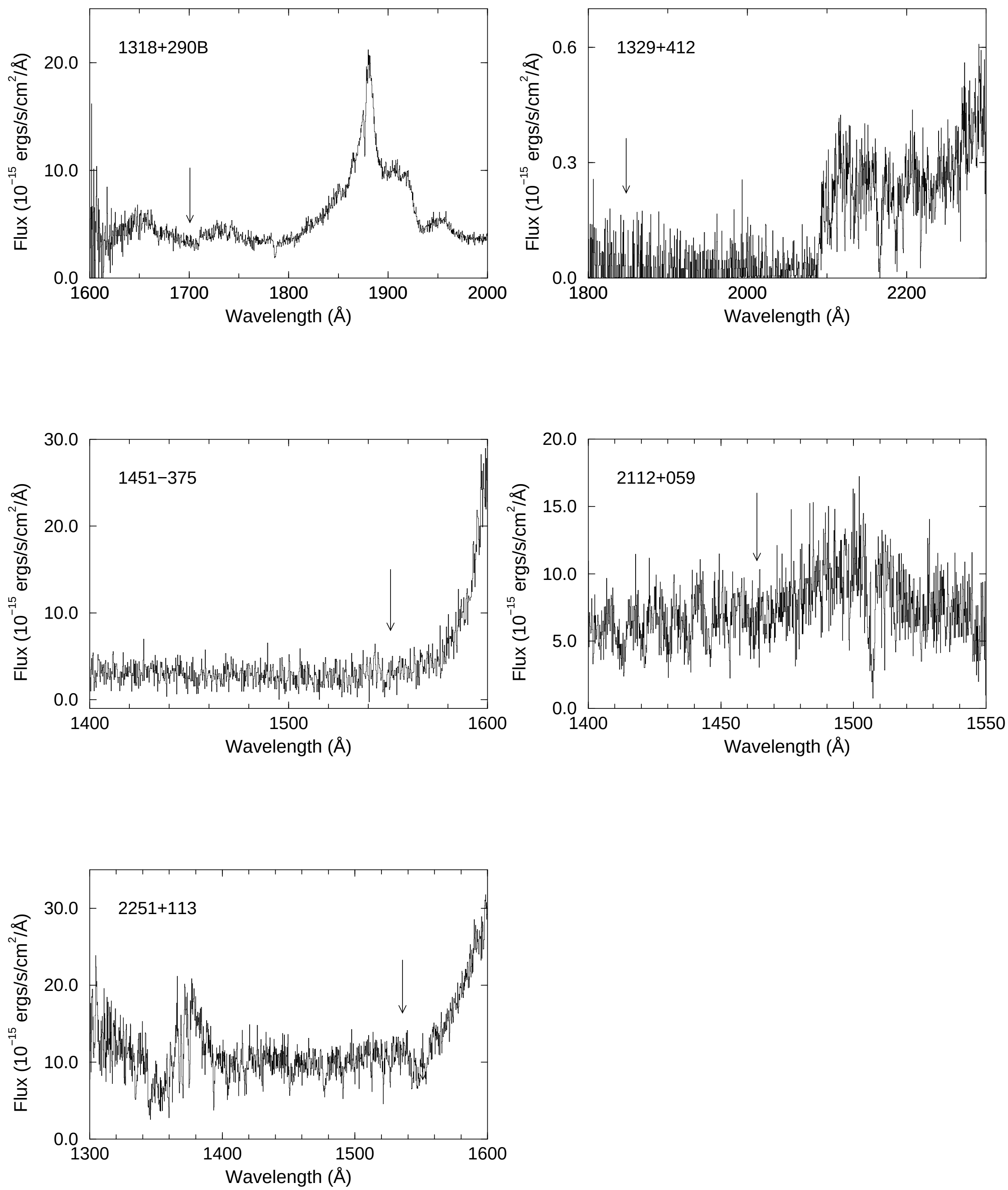
1318+290B
1329+412
1451−375
2112+059
2251+113
Flux (10^{-15} ergs/s/cm^2/Å)
Wavelength (Å)

Fig. 1.— *contd.*